Published online: 2020-06-30

The Effect of Learning English on P300 in Children

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Int Arch Otorhinolaryngol 2021;25(2):e284–e288.

Abstract

Introduction Learning a second language is an essential task in today's world, and is experienced by many children. The cognitive auditory-evoked potential (P300) is related to cognitive activity, attention and concentration, enabling the investigation of the effect of a second language on the central auditory pathway.
Objective To analyze the effects of learning English on P300 latency and amplitude in children and to correlate them with age, time of exposure to English, and time in class.
Method An observational, descriptive, cross-sectional and quantitative study, in which 33 children, aged between 5 and 9 years and 11 months, of both genders participated, 14 of them in the process of learning English (study group) and 19 without this experience (control group). All subjects had their P300 evaluated using the Intelligent Hearing Systems (IHS, Miami, FL, US) Smart EP equipment. A total of 300 binaural stimuli were used in 75 dBnHL, as well as 240 frequent and 60 rare stimuli, using the pairs /ba/ and /di/ respectively.
Results There was a statistically significant difference regarding P300 latency between the groups, and children exposed to English classes had lower latency in this component. No statistical difference was found between P300 amplitudes. No correlation was observed regarding age, time of exposure to English, time in class, and electrophysiological responses.
Conclusion The Children exposed to English classes had the most stimulating auditory pathway, because their P300 had lower latency, being a resource for the speech therapy clinic.

Keywords
► children
► event-related potentials
► P300
► child development
► electrophysiology
► multilingualism

Introduction

Currently, learning a second language is one of the essential tasks in order for a subject to think and act critically,[1] and this is experienced early by many children. Learning a second language has different benefits, such as improvements in cognitive, psychological, social and linguistic processes.[2,3]

In this sense, English is one of the most widely spoken languages in the world, and is, therefore, considered a globalized language.[4] Early contact with this language, or any other language, enables the subject to develop a metalinguistic competence over the languages that transits.[5]

Children exposed early to a second language show effective results in the development of memory, reasoning and attention skills.[5,6] Therefore, childhood is a critical period to

received November 10, 2019
accepted March 7, 2020
published online June 30, 2020

DOI https://doi.org/10.1055/s-0040-1710304.
ISSN 1809-9777.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

learn a second language, since the student has a faster process of brain maturation, unlike in later stages of life.[7]

Regarding the effect on the auditory pathway of the exposure to a second language, there are few studies in the literature that describe such benefits, especially in central auditory processing (CAP),[6,8,9] which is the ability of the auditory pathway to receive, analyze and interpret sound stimuli, making acoustic information from the environment useful. Its operation depends on the organic and functional conditions of the auditory system, as well as the listener's auditory experience, and stimulation of the auditory skills may make them increasingly refined and effective.[10]

In this sense, in a Brazilian study evaluating the auditory processing of bilingual adults, the authors observed that the temporal and figure-background auditory skills for verbal sounds of these subjects were more developed than in monolingual adults.[8] Based on the analysis of the P300 wave, it is also possible to infer about the integrity of the CAP. The P300 is a record of the neuroelectric activity from the thalamus to the auditory cortex that enables us to evaluate the time it takes for sound to be perceived and interpreted by CAP, which is a record of the neuroelectric activity from the thalamus to the auditory cortex that enables us to evaluate the time it takes for sound to be perceived and interpreted by the central auditory pathway.[11] The use of this potential is highlighted in the investigation of some cognitive skills involved in information processing, such as attention, discrimination and auditory memory.[12] The P300 wave, as already mentioned in the literature,[8,9] enables the investigation of the effect of a second language on the central auditory pathway, as it is directly related to cognitive activity, attention and concentration.

It is important to understand the way auditory information is processed by the central nervous system in children who are learning a second language in order to know how this experience influences the auditory pathway of these individuals. The importance of the present study is centered on this aspect, since encouraging the learning of a second language can be a strategy to stimulate the central auditory skills, being an alternative in speech therapy management and also an option to improve the school performance of children.

Considering the aforementioned information, the aim of the present study was to analyze the effect of English classes on P300 responses in children and to correlate the electrophysiological responses with age, time of exposure to English, and time in class.

Methods

This is an observational, descriptive, cross-sectional and quantitative study, which was approved by the Research Ethics Committee of the institution of origin under number 14804714.2.0000.5346. All standards and guidelines of Resolution 466/12 of the Brazilian National Health Council were respected. The study was performed on the Hearing Electrophysiology Ambulatory of a school clinic. Initially, a survey was performed on language schools that offered English language courses for children with a communicative approach, that is, those with the purpose of teaching the language through social interactions and pragmatic use.[13] In total, eight schools were selected, but only six agreed to participate. Afterwards, invitations were made to the children's parents and/or tutors to participate in the study. Similarly, for the sample of children not exposed to English, invitations were distributed to public and private elementary schools that did not offer English classes for this age group. Only the subjects who agreed and whose parents and/or tutors signed the Informed Consent Form (ICF) participated in the study.

A total of 45 children were evaluated, but 12 of them were excluded because they did not fit the profile chosen for the study. Thus, a total of 33 children aged between 5 and 9 years and 11 months of both genders were included in the sample, with normal hearing thresholds up to 8 kHz in both ears,[14] "A"-type tympanometric curves,[15] and acoustic reflexes present bilaterally at normal levels.[16,17] The children did not present alterations in the auditory processing behavioral screening; did not complain of learning and language difficulties; did not have inadequate school performance reported by their parents; and had never played musical instruments.

The sample was then divided into the study group (SG), which was composed of 14 children who attended an English language course, without contact with a third language, and the control group (CG), which was composed of 19 children from public and private regular schools who were not exposed to the process of learning a second language. The SG children had a minimum time of exposure to English of 12 months and a maximum of 48 months, with an average of 32.6 months. Regarding the frequency of the classes, the minimum was once a week, and the maximum twice a week, with each class lasting one hour.

As for the procedures performed for the composition of the sample, we initially applied an adapted questionnaire[9] to collect information about the participants and their experiences with the English language. Then, the external auditory canal was visually inspected using a Klinic Welch Allyn (Skaneateles Falls, NY, US) otoscope, as well as pure tone audiometry (PTA) and acoustic immittance measurements. For those evaluations, we used the Fonix hearing evaluator audiometer (Frye Electronics, Inc., Beaverton, OR, US), FA 12 type I model, with TDH-39 earphones (Telephonics, Farmingdale, NY, US), as well as the AT235 Interacoustics clinical tympanometer (Middelfart, Denmark) with 226-Hz probe tone.

For the behavioral screening of the auditory processing, the Pediatric Speech Intelligibility (PSI) test was applied to the children,[18] and the Scale of Auditory Behaviors (SAB)[19] was answered by parents. The PSI was performed in the contralateral condition with a competitive stimulus (linguistic message) presented to the ear opposite to the one receiving the main stimulus, in a signal/noise of 0 and -40.

The research procedure was the recording of event-related potential P300 wave, using the Intelligent Hearing Systems (IHS, Miami, FL, US) Smart EP equipment. Before the examination, the parents/tutors received some guidelines, such as: not allowing the child to take medication for at least four hours previous to the examination, to perform physical or intellectual activity that promoted fatigue, or to ingest stimulants such as tea, coffee or chocolate, as they may interfere with the results of the evaluation.[12]

An evaluation of the P300 wave was performed with a presentation of 300 binaural stimuli at an intensity of 75dBnHL, with 240 common and 60 rare stimuli, using the pairs /ba/ and /di/ respectively, and respecting the oddball paradigm.[12]

The electrode impedance value was considered to be 3 kohms or lower, with a 510-ms window, alternating polarity, 0.01-Hz low-pass filter and 1,000-Hz high-pass filter. Only the presence of 10% of artifacts from the total of stimuli was considered. To capture the potential, it was necessary to clean the skin with an abrasive paste (Nuprep, Weaver and Company, Aurora, CO, US) and regular gauze. Insertion earphones were used and silver electrodes were fixed using the MaxxiFIX (Neurovirtual, Fort Lauderdale, FL, US) conductive electrolytic paste and microporous tape. The reference electrodes were positioned at the M1 (left mastoid) and M2 (right mastoid), and at Cz (cranial vertex), we placed the active electrode, and connected it to channels A and B at the positive input of the preamplifier. The ground electrode (Fpz) was positioned on the forehead.

The validity of the examination was determined by the number of hits reached by the child, which should be above 90% of the total of rare stimuli presented. If the child did not reach this percentage, the examination would be performed again, preferably at another time.

In order to record the P300 wave, the child sat comfortably in an armchair in alert state and was instructed to pay attention to the rare stimuli /di/, marking on a sheet of paper every time he or she heard them. To ensure counting, training was performed so that there were no misunderstandings. It is known that there is no difference in latency and amplitude values if the count is made mentally or marked on paper.[20]

The electrophysiological responses were analyzed by two qualified judges with theoretical and practical knowledge in hearing electrophysiology, especially in the P300 wave. Then, the markings made by the children were reproduced in the respective examinations in the software of the equipment to obtain the latency and amplitude values with precision.

For the data analysis, the results were tabulated in Microsoft Excel 2010 (Microsoft, Redmond, WA, US) spreadsheets, and the statistical analysis was performed using the Statistical Analysis System (SAS, SAS Institute, Cary, NC, US) software, version 9.2 for Windows. Due to the non-normality of the data, the Mann-Whitney U Test was used to compare the latency and amplitude values of the P300 wave between the groups. The Pearson correlation was used to verify the relationship between electrophysiological responses and the age, the time of exposure, and the time in class variables. Analyses with a confidence level greater than 95% ($p < 0.05$) were considered significant.

Results

►**Fig. 1** shows the difference in P300 latency between the SG and the CG. This difference was statistically significant ($p = 0.0016$).

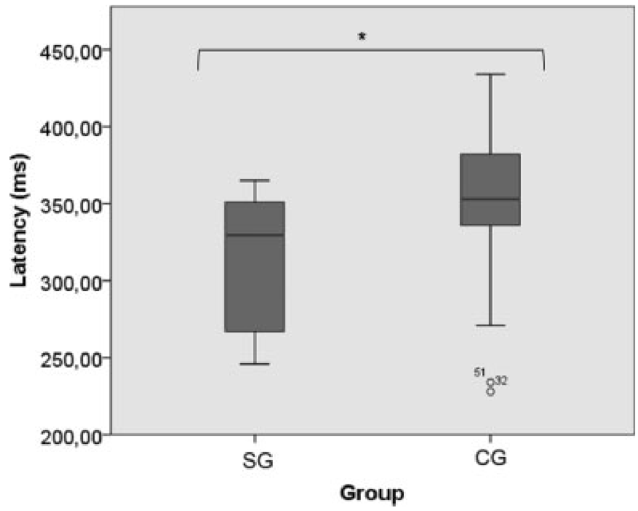

Fig. 1 Comparison of P300 latency between children learning English (the study group, SG) and unexposed children (the control group, CG). Note: * Statistically significant difference ($p = 0.0016$) relative to the Mann-Whitney U-test.

The mean P300 latency for the SG was of 310.6 ± 45.1 ms (mean ± standard deviation), and, for the CG, it was of 346.7 ± 48.9 ms.

As shown in ►**Fig. 2**, the P300 amplitude of both groups did not present a statistically significant difference ($p = 0.7604$).

The mean P300 amplitude value for the SG was of 7.4 ± 2.7 µV, and, for the CG, it was of 7.3 ± 3.2 µV.

►**Table 1** shows the analysis of the correlation between the electrophysiological responses (latency and amplitude) of P300 wave and age, time of exposure to English and time in class of the SG.

No statistically significant correlation was observed regarding the analyzed variables.

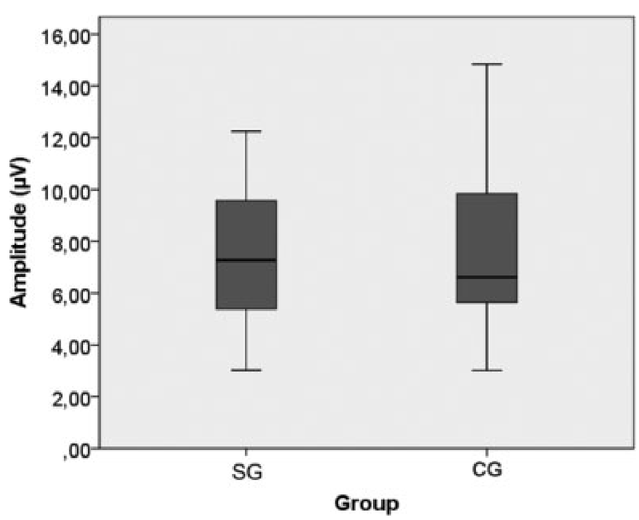

Fig. 2 Comparison of P300 amplitude between children learning English (the study group, SG) and unexposed children (the control group, CG). Note: Mann-Whitney U-test.

Table 1 Correlation among P300 latency and amplitude, age, time of exposure and time in class among children learning English

P300	Age (months)		Time of exposure (months)		Time in class	
	Corr (r)	*p* Value	Corr (r)	*p* Value	Corr (r)	*p* Value
Latency	-0.020	0.946	-0.029	0.923	0.356	0.212
Amplitude	0.095	0.747	0.057	0.847	0.334	0.244

Abbreviation: Corr (r), Pearson correlation.

Discussion

In the present study, the latency of the P300 wave was influenced by exposure to a second language, in this case, the English language, because the results showed that the SG presented statistically lower latency values than the CG (►**Fig. 1**). In this sense, children in the process of learning English can present greater stimulation of the auditory pathway and, consequently, better neural conduction of the acoustic stimulus at the cortical level.

Barac et al[6] also observed lower latencies for the P300 wave in children, but they were bilingual and native English speakers whose second and third languages were French and Spanish respectively. In this study, the children were not bilingual, but they were in the process of learning a second language.

In the literature, there are reports[21] of advantages for bilingual children regarding executive control and greater efficiency in tasks that require the processing of phonological information. In fact, there probably are specific areas of cognitive functioning in which bilingual children excel compared with monolingual children.[21]

Neural areas corresponding to the temporal-lobe auditory-evoked potential – Na and T complex –measure the rate of auditory maturation and language processing, and are sensitive to linguistic experience.[22] Rinker et al[22] observed differences in these areas in bilingual children (English-Spanish and German-Turkish) when compared with monolingual children, more specifically in the latency of the Ta component. Therefore, the authors concluded that the lateral temporal cortex plays an important role in the development of language perception.

In a study[23] of the immediate (30 days) and lasting (after one year) effects of the influence of French music classes on North-American children, there was improved attentional processing of sounds considered relevant and increased ability of suppressing irrelevant sounds. This demonstrates the influence of second language learning on the auditory processing of children. In this specific case, exposure to music may also have contributed to such results.

As for the amplitude values of the P300 component, in the present study, no statistically significant differences were observed between the groups (►**Fig. 2**). However, Barac et al[6] found higher P300 amplitudes among a group of bilingual children when compared with monolingual children. This disagreement between studies may be justified by the fact that participants have different times of exposure to a second language and also because the children in the present study are not bilingual, but are in the process of learning a second language. Thus, the evidenced data from the present study shows that the time of exposure of the individuals was not sufficient to change the magnitude of the synaptic activity, which is interconnected with the perceptual process, when compared with a group without exposure.

In the correlation analysis regarding age, time of exposure and time in class in relation to P300 latency and amplitude, no statistically significant correlation was observed (►**Table 1**). This data suggests that the difference in time of exposure time and time in class of the participants of the present study did not influence the P300 electrophysiological responses.

A year of learning in a second-language classroom may be a short time for electrophysiological changes to be identified when compared with longer times of exposure.[24] Jost et al[24] came to the same conclusion after assessing a long-term potential with Mismatch Negativity (MMN), but passively arising without attention to the sound stimulus, 38 German children, before they began to learn English and after one year of classes.

In another study,[25] the authors scanned changes in brain activity, but with the N400 potential of 12 English-speaking exchange students who were learning German. The study showed electrophysiological changes after five months of intense learning, reinforcing the assumption that a higher level of proficiency implies faster and more automatic visual and auditory information processing.

The benefit of learning a second language in the auditory pathway, and consequently, in auditory processing skills can also help in school performance, since in order to be successful in learning, it is necessary to properly process all auditory information from the outer ear to the auditory cortex.[11] Furthermore, the stimulation of the auditory pathway becomes important considering that classrooms are generally not favorable listening environments, since they do not have acoustic treatment and require a excellent auditory processing on the part of the child.[26]

Finally, the P300 component is a response of the activity of the hippocampus and the auditory and frontal cortex.[12] Moreover, it is considered in the literature a cognitive potential that can constitute cortical activity. Thus, the investigation of the latency of this component, in this study, demonstrated sensitivity to learning a second language, such as English, in the pediatric population. Therefore, stimulating children to learn a second language may be a clinical speech therapy resource because of the improvements in the neural conduction of the acoustic stimulation at the cortical level, benefiting the school performance of these children.

Conclusion

The findings of the present study enable us to conclude that the process of learning English among children has an effect on P300 latency. This benefit may contribute to the speech therapy clinic, as well as improve school performance, considering the increase in the stimulation in the auditory pathway provided by exposure to this language. In the present study, age, time of exposure and time in class time did not influence the P300 electrophysiological responses.

Conflict of Interests
The authors have none to disclose.

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